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Integrated Monitoring System for Growing Grain Crops

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One of the main indicators of food security in Kazakhstan is the volume of grain production. The most important current scientific problem is the development of innovative monitoring systems for growing agricultural products. Farms in Kazakhstan face the problem of low efficiency of the available means of control when growing crops over large areas. The paper presents a mobile application developed by the authors for continuous monitoring of crop conditions using a combination of Earth Remote Sensing (ERS) and Unmanned Aerial Vehicles (UAV) methods, as well as the movement of specialised agricultural machinery for operational farm management. This approach has been shown to improve the quality of grown agricultural products and reduce their cost by increasing control over fuel consumption.

1. Introduction

Agriculture and food security are closely linked. Food security depends on many factors: climate change, crop yields, quantity and quality of arable land, etc. Agriculture has to produce more food to feed a growing population. By 2050, the global population is expected to reach over 9×10^9 people and the consumption of agricultural and food products is expected to increase by more than 75 % (Singh et al., 2022). In 2022, Kazakhstan improved its position in the Food Security Index ranking and ranked 32-nd out of 113 countries (Pyagay et al., 2021).

One of the main indicators of food security in Kazakhstan is the volume of grain production. According to the Food and Agriculture Organization of the United Nations, Kazakhstan is among the top 20 countries in the world in barley production. Almost all farms in Kazakhstan face the problem of low efficiency of available controls when growing crops over large areas. A farmer needs to analyse a huge amount of data to make the right decision about growing a crop: weather conditions, crop rotation, agrochemical conditions of the soil, etc. This greatly complicates the farmer's task and leads to crop losses. Global experience gained in the use of information technology in agriculture provides a solution to this problem (Velusamy et al., 2021). The most important current scientific problem is the development of innovative systems for monitoring the cultivation of agricultural products. (Mukhamedova et al., 2022). The time has come to use operational monitoring information to solve agronomic problems in order to approach precision farming. It is not possible to solve precision farming tasks without the use of UAVs (Mogili et al., 2018). Drones have long been used in agriculture. Japan is the first country to use drones in agriculture back in 1983 (Sheets, 2018). China started using drones in agriculture about ten years ago. Drone manufacturers hope that a new generation of farmers will emerge through this technology (Hui et al., 2019). The process of introducing UAVs into agriculture is necessary, just like the mechanisation of agriculture in the 20th century. The only thing is that to use UAVs effectively in agriculture, farmers not only need to have a good understanding of the data obtained but also to be able to use the information in practice (Galushka et al., 2020). Drones can be used to optimise crop selection, water availability, fertiliser availability, etc. Drones can help to reduce the overall cost of agricultural production and ensure decent yields and grain quality. Drones are used to improve agricultural productivity as well as to improve measurement accuracy, real-time information collection and development of productive agriculture.

Inefficient use of farm machinery is one of the sources of additional costs on farms. Many farmers are unaware that the costs associated with growing crops can be reduced in several ways. For example, keeping a complete

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record of all machinery movements, determining optimum routes for machinery, minimising fuel and lubricant costs, and reducing machinery downtime. To implement these measures, it is necessary to use GPS trackers. These are devices that, based on a global positioning system (GPS), determine the location of an object and transmit the data to a remote server (Enge, 1994). GPS trackers are commonly used to track vehicles, construction and agricultural machinery. A triangulation method is used to determine the device’s location by measuring the signal delay time between the tracker and the satellites (Shen and Stopher, 2014). Location data is subsequently transmitted to a remote server via a mobile network (GSM) or internet network (Wi-Fi) (Zhu et al., 2018), allowing users to track the movement and use of equipment in real time.

Dedicated monitoring platforms such as Gurtam Wialon (Gurtam, 2021a), GPSWOX (GPSWOX, 2021) and Navixy (Navixy, 2021) are used to work with GPS trackers. These platforms allow for managing location data, real-time object tracking, route analysis, equipment status monitoring and many more. Gurtam Wialon API provides the access to the functionality of the Wialon platform via standard protocols such as HTTP, JSON, and XML (Gurtam, 2021b). This allows integration of Wialon with other services, developing of custom tracking applications, and the creation of plug-ins for the Wialon platform. Another product, GPSWOX API, offers developers access to the functionality of the GPSWOX platform using standard protocols such as HTTP and JSON. The API can be used to integrate GPSWOX with other services, create custom tracking applications and much more. The Navixy API allows developers to access the Navixy platform functionality using standard protocols such as HTTP and JSON. This allows for integrating Navixy with other services, developing custom vehicle tracking applications and creating plugins for the Navixy platform. In the future, integration of GPS trackers with other Internet of Things (IoT) devices can be expected to improve the accuracy and efficiency of the monitoring system.

The paper discusses new methods of crop surveillance using remote sensing and UAVs, movements of specialised agricultural machinery, etc.

2. Materials and methods

The object of the study was experimental fields located in the east of Kazakhstan. The climate is sharply continental and dry. The high degree of continentality is manifested in large annual and daily temperature amplitudes and instability of climatic indicators over time. Summer temperatures sometimes rise to 40 – 45 °C, and in the winter drop to - 40 °C. Soils are predominantly common chernozems. A SenseFly eBee X UAV (manufactured by senseFly, Switzerland) with a Parrot Sequioa+ multispectral camera was used to monitor the fields. It allows imaging in four specific visible and invisible spectral bands as well as RGB images in just one flight (Figure 1). Sentinel-2 L2A satellite images from the EO Browser open access platform were used as remote sensing data.

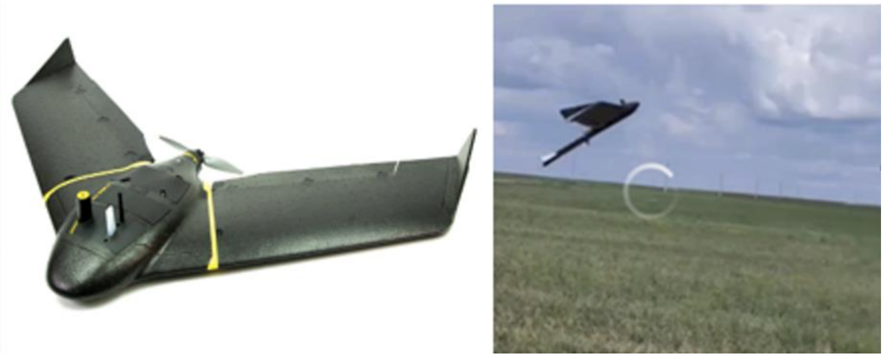

Figure 1: SenseFly eBee X

In order to receive data on the movement of agricultural machinery, channels are created on the service that receives information from the trackers. Each channel is a server that decrypts the messages and stores them for further processing.

3. Results and discussion

UAVs with multispectral cameras are particularly important for monitoring crops, as drones' images can provide a complete picture of plant development at every stage of growth, regardless of weather conditions. One of the main tasks that UAVs are used for in agriculture is the construction of vegetation index maps. The most common of these is the Normalised Relative Vegetation Index (NDVI). The index was calculated from the red and nearinfrared channel surveys. Figure 2 shows the change in NDVI value obtained using a UAV when flying over one of the experimental fields with spring barley crops in different phases of vegetation. It follows from the data obtained that the value of NDVI of spring barley crops in the same field area varies depending on the phases of crop development. The index increases with each successive growing season and decreases with the stage of spring barley maturity. During the growing season - earing - the NDVI values of spring barley crops reach a maximum value. It is recommended to make yield predictions based on the highest NDVI values during the earing period.

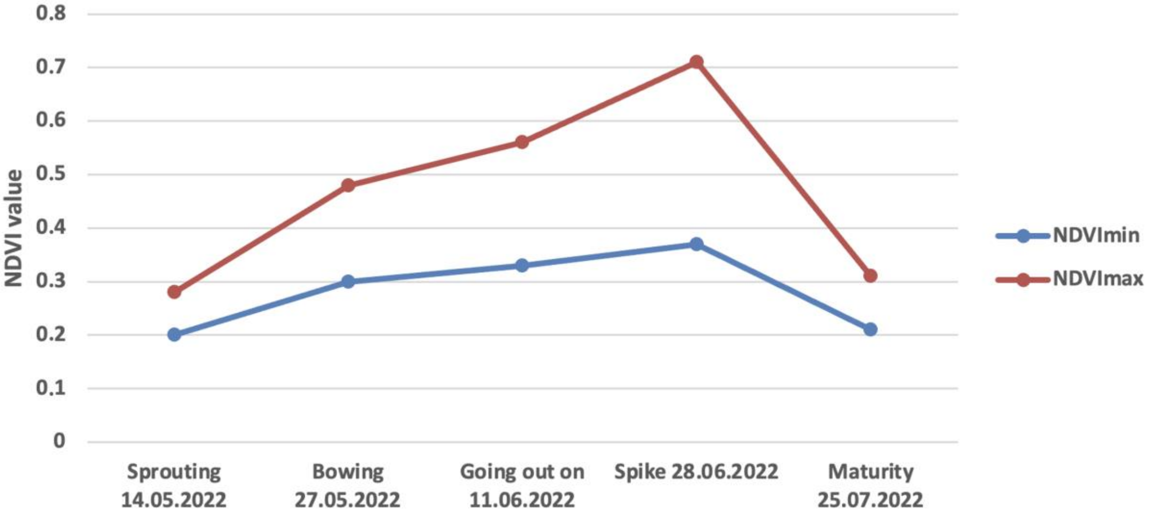

Figure 2: Change in NDVI value of spring barley crops in experimental field c, depending on the phase of vegetation

Monitoring using processed satellite images of the field is shown in Figure 3. Figure 3a shows an image of an experimental field with an area of 132 ha obtained with the help of Google Maps. Figure 3b and 3c show the result of satellite images processing using the authors' method (Kabzhanova et al., 2022) with obtaining the field contour and one of the vegetation indices (NDVI) characterizing the plants development during their growth stages. Parallel 3-level field monitoring by different remote sensing methods in combination with ground-based field surveys allows obtaining more complete and operative information on crop condition for better management of agronomic processes.

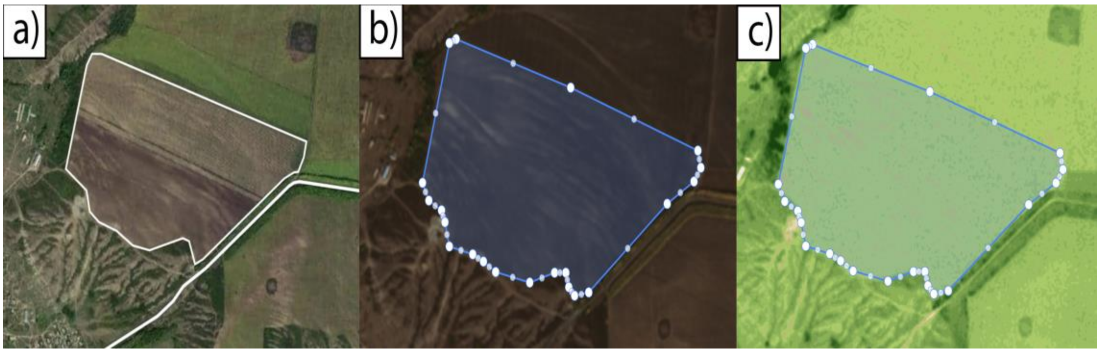

Figure 3: Experimental field with barley crops (a) Field contour (Google Maps image); (b) Space image; (c) NDVI

The methodology and visualisation of the process of monitoring the movement of specialised agricultural machinery is shown schematically in Figure 4.

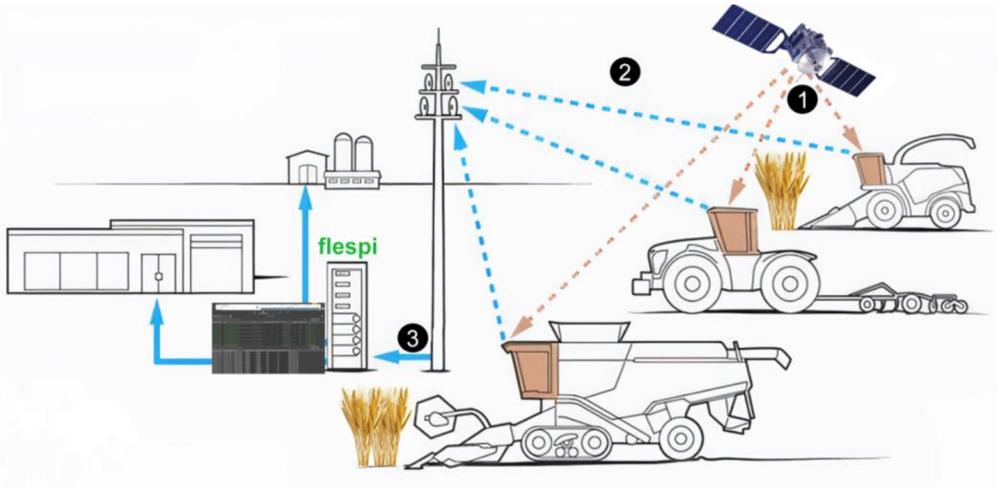

Figure 4: Visualisation of the tracker data transmission process

Figure 4 shows the process of acquiring data on the location of the machinery using satellites under Figure 1, the process under Figure 2 shows the transfer of data and machine settings via the mobile network to the server, and Figure 3 shows the data import with further processing on the Flespi server.

The machine movement monitoring system implemented in practice on the fields of the pilot farm (as individual steps) is shown in Figure 5. The procedure for obtaining data on the movement of the MT3 920 M tractor manufactured in the Republic of Belarus is shown in the form of a block diagram. It can be seen that channels are formed on the service to receive data from trackers. The channel is a server which performs decoding of messages and their storage. All trackers send information to the storage located on the server of the Department of Information Technologies of the East Kazakhstan Technical University named after D. Serikbayev (Ust-Kamenogorsk, Kazakhstan). A virtual device has been created on the Flespi platform for data delimitation. This device is an instance storing tracker IMEI code to identify packets, tracker type (to identify transmitted data, as it may be different depending on the type of tracker) and different configurations for data storage. In the section of this device, integrated into the Agronomist Tablet mobile application developed by the present authors, it is possible to view the location of machinery and other telemetry data. It is possible to log the device, configure the device, send a command to it and view the data processed by the calculator. The calculator is an instance with a data processing algorithm. For example, the algorithm for detecting refuelling includes a record of the algorithm for determining the increase in fuel quantity, date and volume of refuelling, and the algorithm for detecting journeys where two points are used (the moment the engine is started and stopped). All packets collected during this period are recorded on the trip, allowing the route, duration and distance of the trip to be viewed. Data from the platform is exported using an API or MQTT broker. Both options provide real-time information on channels, devices and calculators.

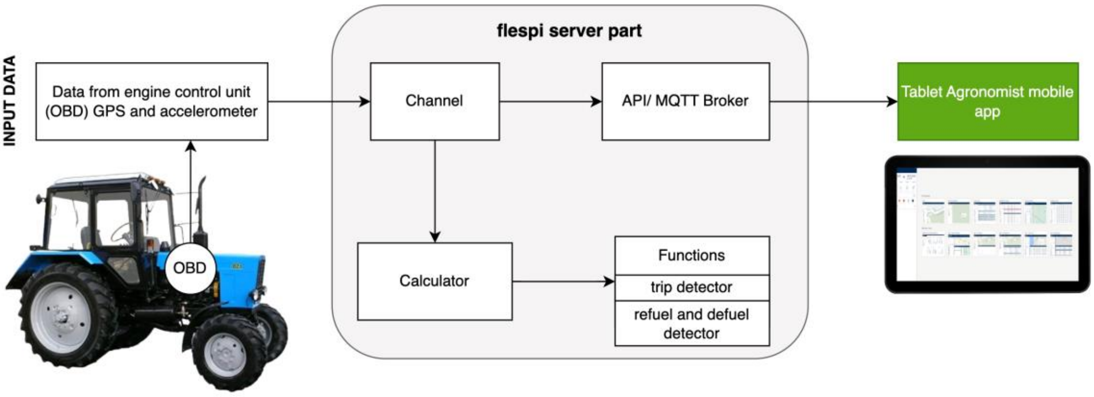

Figure 5: Flowchart describing the methodology of the agronomist's tablet mobile application

Figure 6 shows the installation of the GPS-tracking system equipment set for agricultural machinery. Figure 6a shows the installation of the GSM amplifier antenna on the roof of the MT3 920 M tractor, Figure 6b shows the main tracking terminal installed in the tractor driver's cab, and Figure 6c shows the installed fuel level sensor.

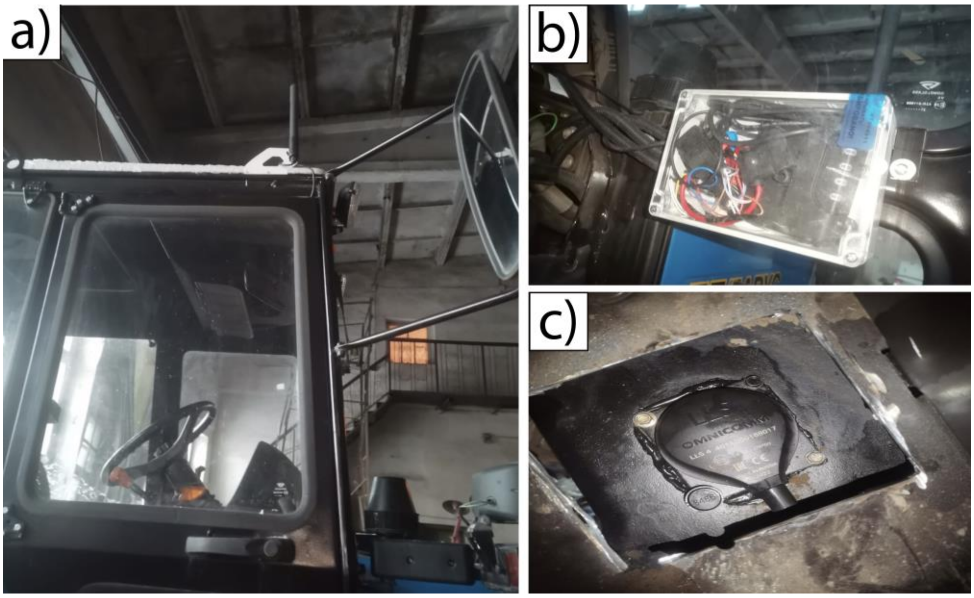

Figure 6: Installed tracker equipment kit a) GSM amplifier antenna; b) Tracker terminal; c) Fuel level sensor

Although satellite navigation provides high positioning accuracy, there are certain limitations, such as errors caused by atmospheric phenomena, poor signal quality in urban canyons or hard-to-reach locations. In some cases, it may be necessary to use additional technologies such as Wi-Fi, Bluetooth, or inertial navigation systems to improve positioning accuracy. However, it should be noted that the use of GPS trackers may raise privacy and data protection concerns. It is important to consider legal regulations and rules on the use of monitoring systems to protect information on the location and movement of machinery, as well as the ethical use of such systems.

GPS trackers can also be integrated with Artificial Intelligence (AI) and Machine Learning (ML) to perform automatic analysis of location and usage data. Such integration can be particularly useful in identifying equipment anomalies, optimising transport routes and performing other data analysis tasks. By automating these analyses, GPS trackers can help reduce staff workloads, improve operational efficiency and enhance decision-making capabilities. A set of new crop monitoring methods developed based on UAV and RS data, as well as telemetry systems for specialised agricultural machinery, have been integrated into the Agronomist Tablet mobile application (Figure 7).

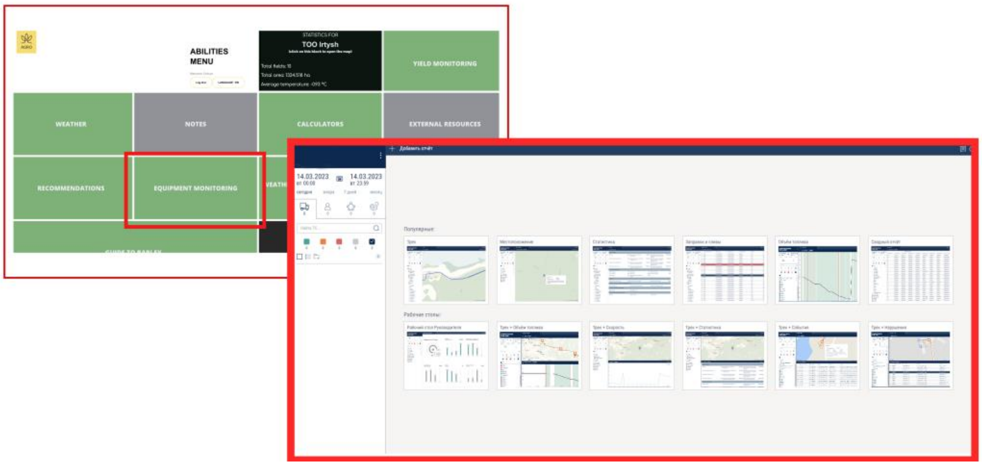

Figure 7: Developed "Tablet Agronomist" mobile app, with integrated machinery telemetry module

4. Conclusions

The authors of this paper developed the Agronomist Tablet mobile application with the integration of a new complex of 3-level monitoring of agricultural land based on UAV and remote sensing data combined with ground-based field surveys, which provide more complete and timely information on crop conditions for better management of agronomic processes.

The authors reviewed the main aspects of GPS trackers, such as their working principle, third-party software and APIs that help in GPS tracking, as well as future trends and opportunities in this field. GPS trackers are shown to play an important role in tracking and controlling machinery and as technology advances, their capabilities will continue to grow, making them an indispensable tool for many industries and applications. As technology advances and satellite systems improve, the accuracy of GPS trackers is expected to improve, providing users with even more accurate location and equipment usage data. This development may be particularly important for some industries and applications. Wireless technologies such as 5G and Low Power Wide Area Networks (LPWAN) are being developed and deployed to improve the energy efficiency of GPS trackers and increase their operating range. This, in turn, will enable the use of GPS trackers in regions with limited mobile phone coverage and in remote areas.

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